BONDING MEMBER AND ELECTROSTATIC CHUCK

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from prior Japanese Patent Application P2003-062040 filed on March 7, 2003; the entire contents of which are incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a bonding member including two or more of different kinds of members by joining the different kinds of members together. More particularly, the present invention relates to an electrostatic chuck which can be suitably used in a semiconductor manufacturing device.

2. Description of the Related Art

Conventionally, for bonding of a ceramics member and a metal member, there is a method using a brazing material. However, in a cooling operation after the bonding performed at high temperature, there occurs thermal stress caused by a difference in a coefficient of thermal expansion between different kinds of members or between the members and a brazing material used for joining these different kinds of members. Accordingly, a bonding interface is peeled off or cracks occur in the vicinity of the bonding interface when one of the members is fragile. Thus, desired bonding strength and airtightness may not be obtained. Products, in which such problems as described above arise in a manufacturing process thereof, have to be disposed of as defective products. Thus, the problems described above

contribute to increasing product costs of these bonding members. Moreover, if there is a heat cycle when the members are used, the problems described above arise after the members are used for a fixed period of time. Accordingly, the problems also contribute to lowering reliability of the product.

In consideration of the present situation described above, there has been studied a bonding method which maintains moderate bonding strength between different kinds of members, without causing a phenomenon of lowering bonding strength due to thermal stress in the vicinity of a bonding interface during a cooling operation after bonding performed at high temperature and without generating cracks in a cooling operation for a member vulnerable to the thermal stress. For example, there is disclosed a method for obtaining a bonding layer by using brazing filler metal as a base and adding particles which lower thermal stress to the brazing filler metal (for example, see Japanese Patent No. 3315919). Moreover, there is also disclosed a method for joining different kinds of members together when a width of a gap existing between wall surfaces of the different kinds of members in a fitting structure portion is narrow (for example, see Japanese Patent Laid-Open No. 2001-10873). Furthermore, there is also disclosed a bonding adhesive composition which includes brazing filler metal and a mixture of at least two kinds of particles different from the brazing filler metal in wettability (for example, see Japanese Patent Laid-Open No. 2001-122673).

Moreover, as a product which requires bonding of a ceramics member and a metal member, for example, an electrostatic chuck used in a semiconductor process or the like is enumerated. In this electrostatic chuck,

the ceramics member and the metal member are joined together in a portion of a substrate, which has built-in electrodes and is made of ceramics or the like, and a terminal, which supplies power to the built-in electrodes and is made of gold-plated molybdenum or the like.

As described above, there have been known various methods for joining a ceramics member and a metal member, which never cause a phenomenon of lowering bonding strength nor generate cracks in a cooling operation for a member vulnerable to thermal stress. However, even by using the methods described above, residual stress is likely to be concentrated in a corner portion when different kinds of members are joined by adopting a structure in which a concave portion is fitted to a convex portion. Therefore, cracks sometimes occurred.

SUMMARY OF THE INVENTION

A first aspect of the present invention is to provide a bonding member, including, a) a ceramics member having a concave portion, b) a metal member which has a convex portion fitted to the concave portion, c) a first bonding material which joins a bottom portion of the concave portion of the ceramics member and a tip portion of the convex portion of the metal member and has a porous structure including particles and brazing filler metal that covers a corner between tip and side portions of the metal member, and d) a second bonding material which includes brazing filler metal that joins a side portion of the concave portion of the ceramics member and a side portion of the convex portion of the metal member.

A second aspect of the present invention is to provide an electrostatic chuck for absorbing an object to be processed, the electrostatic chuck,

comprising, a) a substrate which includes an electrode therein and has a concave terminal bonding hole, b) a terminal which is a member made of a different material from that of the substrate and supplies power to the electrode, c) a bottom portion bonding material which joins a bottom portion of the terminal bonding hole and a tip portion of the terminal and has a porous structure including particles and brazing filler metal that covers a corner between tip and side portions of the terminal, and d) a side portion bonding material which includes brazing filler metal that joins a side portion of the terminal bonding hole and the side portion of the terminal.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a cross-sectional view of an electrostatic chuck according to an embodiment of the present invention.

Fig. 1B is an enlarged view of a bonding portion between a terminal and an electrode, which is shown in Fig. 1A.

Fig. 1C is an enlarged view of a corner portion of the terminal and a terminal bonding hole, which is shown in Fig. 1B.

Fig. 2 is a flowchart showing a method for manufacturing the electrostatic chuck according to the embodiment of the present invention.

Fig. 3 is a flowchart showing a method for joining the terminal of the electrostatic chuck according to the embodiment of the present invention.

Fig. 4A is a cross-sectional SEM photograph of a terminal bonding portion of an electrostatic chuck in example 1.

Fig. 4B is an enlarged view of section A in Fig. 4A.

Fig. 5A is a cross-sectional SEM photograph of a terminal bonding portion of an electrostatic chuck in comparative example 1.

Fig. 5B is an enlarged view of section B in Fig. 5A.

DETAILED DESCRIPTION OF THE INVENTION

Various embodiments of the present invention will be described with reference to the accompanying drawings. It is to be noted that the same or similar reference numerals are applied to the same or similar parts and elements throughout the drawings, and the description of the same or similar parts and elements will be omitted or simplified.

A bonding member according to an embodiment of the present invention includes: a first member having a concave portion; a second member which is a member made of a different material from that of the first member and has a convex portion fitted to the concave portion; a first bonding material which joins a bottom portion of the concave portion of the first member and a tip portion of the convex portion of the second member and has a porous structure including particles and brazing filler metal that covers a corner between tip and side portions of the second member; and a second bonding material which includes brazing filler metal that joins a side portion of the concave portion of the first member and a side portion of the convex portion of the second member.

As a combination of two or more of different kinds of members to be used in the bonding member according to the embodiment of the present invention, enumerated are, for example: a combination of a ceramics member such as aluminum nitride and silicon nitride and a metal member such as molybdenum, Fe-Ni-Co alloy and tungsten; and a combination of different kinds of ceramics members which are made of different raw materials from each other. To be more specific, there is enumerated a bonding member

which is used in manufacture of a semiconductor wafer and is formed by connecting and joining an aluminum nitride member, which exerts an electrostatic chuck function and a heater function by use of built-in metal electrodes and metal heating elements, and a metal molybdenum member, for example, which is joined as a terminal supplying power to the built-in metal electrode member and the like.

Hereinafter, description will be given of the case, as an example, where an electrostatic chuck is used as the bonding member according to the embodiment of the present invention.

Fig. 1A shows an example of the electrostatic chuck according to the embodiment of the present invention. The electrostatic chuck includes: a substrate 2 including an electrode 3; and a terminal 1 which supplies power to the electrode 3. The substrate 2 has a rough disc shape made of an aluminum nitride sintered body and has the electrode 3 buried therein. The electrode 3 is made of metal such as molybdenum and may be a wire mesh electrode or a screen printing electrode. At a supporting portion side of the substrate 2, the terminal 1 is buried. An upper surface of the terminal 1 is connected to the electrode 3. An end face of the terminal 1 is exposed to a back of the substrate 2. The terminal 1 is made of, for example, molybdenum subjected to gold plating.

Fig. 1B is an enlarged view of a bonding section of the terminal 1 and the electrode 3, which are shown in Fig. 1A. Fig. 1B is turned upside down from Fig. 1A. The substrate 2 has a concave terminal bonding hole 8 for joining the terminal 1. At a bottom of the concave terminal bonding hole 8, the electrode 3 is exposed. A tip portion of the terminal 1 and the electrode 3 are joined by a bottom portion bonding material 4, and a side of the

terminal 1 and a side of the terminal bonding hole 8 are joined by a side portion bonding material 5. In the terminal 1, a vertical direction vent hole 6 and a horizontal direction vent hole 7 are provided.

As shown in Fig. 1C, the bottom portion bonding material 4 joins the terminal 1 and the electrode 3 so as to cover a corner between the tip and side portions of the terminal 1. Moreover, a corner radius R1 between the tip and side portions of the terminal 1 and a corner radius R2 between the bottom and side portions of the terminal bonding hole 8 are designed to have a relationship of $R1 \geqq R2 \times 0.6$. As described above, the corners of the terminal 1 and the terminal bonding hole 8 are designed. Thus, it is possible to effectively prevent cracks in a corner portion where stress is concentrated. Furthermore, the corner radius R1 between the tip and side portions of the terminal 1 is 0.3 mm or more. In a conventional electrostatic chuck, the corner radius R1 of the terminal 1 is as small as about 0.1 mm. Thus, by increasing the radius as described above, it is made easier for the bottom portion bonding material 4 to cover the corner.

The bottom portion bonding material 4, which is porous, may be made of only brazing filler metal. However, it is preferable that the bottom portion bonding material 4 includes brazing filler metal and particles. In order to lower thermal stress, as the particles, at least two or more kinds of particles are used, which are different from the brazing filler metal in wettability. The brazing filler metal and particles having good wettability with the brazing filler metal and particles having bad wettability with the brazing filler metal are mixed together and the brazing filler metal is melted. Accordingly, the brazing filler metal permeates through the foregoing particles and a bonding layer is formed. The brazing filler metal and the

particles are mixed at a ratio of 70:30 to 10:90 and used. Moreover, the bonding may be also made by previously filling a predetermined amount of particles in bonding spots and pouring a predetermined amount of brazing filler metal in its melted state thereinto. It is desirable that a thickness of the bottom portion bonding material 4 is 0.1 to 0.6 mm.

As the brazing filler metal used for the bottom portion bonding material 4, enumerated are: one including noble metal, such as Au, Ag, Cu and Pd, as a base; a general-purpose brazing filler metal including metal, such as Al and Ni, as a base; and the like. There is no particular limitation on the materials. Accordingly, more suitable ones may be selected based on a relationship between the brazing filler metal and a property of a member to be joined. It is desirable that porosity of the bottom portion bonding material 4 after bonding is 20 to 80 %.

Moreover, as the particles, suitably used are: ceramic particles; cermet particles which are a composite material of ceramic and metal; low thermal expansion metal particles; and the like. As the ceramic particles, particles of silicon nitride, aluminum nitride, alumina, silicon carbide and the like are enumerated. As the cermet particles, particles of Ni-Al_2O_3, Cu-Al_2O_3 and the like are enumerated. As the low thermal expansion metal particles, particles of metal such as molybdenum and tungsten, which have a low coefficient of thermal expansion at high temperature, are enumerated. In order to efficiently lower the thermal stress, it is required to keep an average particle size of the materials described above within a fixed range. The average particle size is preferably 1 to 100 μm, more preferably 30 to 80 μm. It is needless to say that there is no harm in mixing two or more kinds of particles having different average particle sizes from each other and using

the mixture. In the case of using the ceramic particles, wettability thereof with the brazing filler metal becomes a problem. Thus, it is required to plate a surface of the particles with metal such as Ni, Cu and Ag, for example, or to cover the surface with coating of Au, Ag, Ti or the like by sputtering. A plating method is not particularly limited. Electroless plating and the like are suitably used. In this event, it is desirable that a thickness of the plating is 1 to 5 μm.

Moreover, the wettability with the brazing filler metal differs by mixing coated particles and uncoated particles. Thus, porosity of the first bonding material after being joined can be controlled. A mixture ratio of the coated particles and the uncoated particles is preferably within 10:90 to 90:10, more preferably 30:70 to 70:30.

The side portion bonding material 5 includes brazing filler metal. As the brazing filler metal used for the side portion bonding material 5, enumerated are: one including noble metal, such as Au, Ag, Cu and Pd, as a base; a general-purpose brazing filler metal including metal, such as Al and Ni, as a base; and the like. There is no particular limitation on the materials. Accordingly, more suitable ones may be selected based on a relationship between the brazing filler metal and a property of a member to be joined. It is desirable that porosity of the brazing filler metal is 20 to 80 %. The side portion bonding material 5 has a two-layer structure. In the case of using brazing filler metal of Al-Ni-Au, there are an Al-rich layer and an Al-Ni-Au intermetallic compound layer.

Moreover, it is desirable that a thickness of the side portion bonding material 5 is 0.008 to 0.012 times a diameter of the terminal 1. When the thickness thereof is 0.012 times the diameter or more, residual stress is

increased by thermal expansion. Meanwhile, when the thickness thereof is 0.008 times the diameter or less, there is only a hard intermetallic compound layer. Thus, a stress absorption effect is lost. In either case, cracks are likely to occur.

Moreover, the terminal 1 has therein a bonding material housing hole 9 which houses a bonding material for joining the terminal 1 and the substrate 2 or the electrode 3. The terminal 1 having the bonding material housed in the bonding material housing hole 9 is placed in the terminal bonding hole 8 and bonding is made. Thus, the terminal 1 can be joined with the substrate 2 or the electrode 3.

Moreover, the terminal 1 has a vent hole running in a vertical or horizontal direction in the terminal 1. The vent hole 6 or 7 can let gas escape to the outside, the gas being generated from the bonding materials in bonding. Thus, the bottom portion bonding material 4 and the side portion bonding material 5 sufficiently permeate between the terminal 1 and the terminal bonding hole 8. Moreover, it is possible to prevent wicking of the bonding materials. Fig. 1B shows both of the vertical direction vent hole 6 and the horizontal direction vent hole 7. However, it is needless to say that the terminal 1 may have any one of the vent holes.

In the electrostatic chuck according to the embodiment of the present invention, the bottom portion bonding material 4 covers the corner between the tip and side portions of the terminal 1. Thus, it is possible to prevent cracks caused in the corner portion by the concentrated stress. Accordingly, in the electrostatic chuck according to the embodiment of the present invention, cracks are unlikely to occur in the substrate, which includes a member vulnerable to thermal stress, in a cooling operation after bonding.

Moreover, when the corner radius between the tip and side portions of the terminal 1 is R1 and the corner radius between the bottom and side portions of the terminal bonding hole is R2, the condition of $R1 \geqq R2 \times 0.6$ is satisfied. Accordingly, there is a difference between the corner radius of the terminal 1 and the corner radius of the terminal bonding hole 8. Thus, it becomes easy for the bottom portion bonding material 4 to cover the corner of the tip portion of the terminal 1. Consequently, more sufficient covering is made possible. Furthermore, the corner radius between the tip and side portions of the terminal 1 is set as large as 0.3 mm or more. Thus, the bottom portion bonding material 4 can cover the corner of the tip portion of the terminal 1. Consequently, bonding strength between the substrate and the terminal can be maintained.

Similarly, in the bonding member according to the embodiment of the present invention, the first bonding material which joins the bottom portion of the concave portion of the first member (for example, ceramics member) and the tip portion of the convex portion of the second member (for example, metal member) and covers the corner between the tip and side portions of the second member. Thus, it is possible to prevent cracks caused in the corner portion by the concentrated stress. Accordingly, in the bonding member according to the embodiment of the present invention, cracks are unlikely to occur in the substrate, which includes a member vulnerable to thermal stress, in a cooling operation after bonding. Moreover, when the corner radius between the tip and side portions of the convex portion 1 is R1 and the corner radius between the bottom and side portions of the concave portion is R2, the condition of $R1 \geqq R2 \times 0.6$ is satisfied. Accordingly, there is a difference between the corner radius of the convex portion and the corner

radius of the concave portion. Thus, it becomes easy for the first bonding member to cover the corner of the convex portion. Consequently, more sufficient covering is made possible. Furthermore, the corner radius between the tip and side portions of the convex portion is set as large as 0.3 mm or more. Thus, the first bonding member can cover the corner of the convex portion. Consequently, bonding strength between different kinds of members can be maintained.

Moreover, the bonding member according to the embodiment of the present invention has the vent hole penetrating in the vertical or horizontal direction inside the convex portion from the bottom portion of the convex portion. This vent hole can let gas escape to the outside, the gas being generated from brazing materials or the like in bonding. Thus, the first and second bonding materials sufficiently permeate between the convex portion and the concave portion. Moreover, it is possible to prevent wicking of the brazing filler metal.

Next, description will be given of a method for manufacturing the electrostatic chuck according to the embodiment of the present invention. Here, with reference to Fig. 2, description will be given of processing up to a stage before the terminal is joined.

(a) First, a material of the substrate is adjusted (S201). Specifically, as a raw material of the substrate of the electrostatic chuck, oxide additives are added to an aluminum nitride powder. As the oxide additives, yttria, ceria and the like are used. Thereafter, the aluminum nitride powder and the oxide additives are mixed. As a mixing method, for example, a large ball mill device called a trommel, in which a container itself rotates, is used technically. Time required for mixing by use of the trammel

is, for example, about 30 minutes. Granulation is performed by adding a binder to the raw material powder.

(b) Next, powder calcination is performed (S202). Normally, calcination is performed after formation processing. However, in the case of manufacturing an electrostatic chuck which has a buried electrode made of metal such as molybdenum, the electrode undergoes oxidation due to the calcination. Accordingly, the calcinations is performed before the formation processing.

(c) Next, the electrode is buried and the formation processing of the aluminum nitride powder is performed (S203). As a forming method, cold isotropic pressing (Cold Isostatic Pressing: CIP) processing may be used, in which a uniaxial compact obtained by a mold forming method is subjected to isotropic forming processing to improve a compact density and eliminate unevenness. It is also possible to obtain a compact by filling a raw material powder directly in a rubber mold and performing the CIP processing, without performing mold formation.

(d) Next, the aluminum nitride powder after formation is sintered to produce an aluminum nitride sintered body (S204). As this sintering method, an atmospheric pressure sintering method or hot pressing can be used. In the hot pressing, a raw material powder or a compact is filled in or inserted into carbon jigs and burned under uniaxial pressure of 30 to 50 MPa. Accordingly, the hot pressing is suitable for burning of a ceramics material which is hard to be densified by normal atmospheric pressure sintering. Furthermore, a hot isostatic pressing (HIP) method, in which the principle of CIP is applied to burning, can be also used.

(e) Next, the aluminum nitride sintered body is subjected to

processing for placing the terminal (S205). Specifically, in the aluminum nitride sintered body to be the substrate, a concave terminal bonding hole for joining the terminal is formed. As this processing, cutting and polishing by use of diamond tools and the like are enumerated. Besides the above, ceramics processing by laser processing, ultrasonic machining, sand blasting or the like is also possible.

Next, with reference to Fig. 3, description will be given of a step of joining the terminal with the substrate of the electrostatic chuck.

(a) First, the terminal bonding hole of the substrate is cleaned (S301). The cleaning is performed by use of acetone, isopropyl alcohol (IPA), ammonia, pure water and the like. Thereafter, the bottom and side of the terminal bonding hole is coated with about 1 to 5 μm of Ni plating (S302). Next, a mixture of Ni-plated ceramic particles and unplated ceramic particles is laid on the Ni-plated bottom of the hole and is made smoothed.

(b) Meanwhile, as to the terminal, molybdenum is processed to have a shape of the terminal and a nickel coating is applied thereto as an undercoat. Thereafter, the terminal is coated with about 10 μm of gold plating. Before the plating, the corner radius R1 between the tip and side portions of the terminal is set to 0.3 mm or more. Moreover, the corner radius R1 between the tip and side portions of the terminal and the corner radius R2 between the bottom and side portions of the terminal bonding hole are processed to have a relationship of $R1 \geqq R2 \times 0.6$. Moreover, the bonding material housing hole 9 is formed in the tip of the terminal and the vent holes 6 and 7, which are connected to the bonding material housing hole 9, are formed in the terminal. Thereafter, particles are filled in the bottom portion so as to cover the corner between the bottom and side portions of the

terminal bonding hole 8. Subsequently, the terminal 1 having brazing filler metal set in the bonding material housing hole 9 is placed in the terminal bonding hole 8 (S303).

(c) Next, a load is applied to the substrate 2 from above the terminal 1 (S304). The load is, for example, about 125 g. Subsequently, bonding is performed in a vacuum furnace (S305). As conditions of the bonding, for example, the substrate is heated at 700℃ for 10 minutes. In this event, the brazing filler metal set in the bonding material housing hole 9 of the terminal 1 is melted to permeate through the particles. Thus, a bonded composition including the brazing filler metal and the particles forms the bottom portion bonding material 4. Moreover, the brazing filler metal permeating through the side forms the side portion bonding material 5. Thereafter, cooling processing is performed. Cooling time may be determined in consideration for characteristics of different kinds of members to be joined and the like. Normally, the cooling time is within 1 to 10 hours. It is more preferable to adopt an annealing method in the cooling operation since an influence of thermal stress can be significantly lowered. Note that the annealing method means cooling performed for about twice the time spent for the normal cooling method or more. Thus, the annealing can minimize the influence of the thermal stress on the bonding portion.

(d) Thereafter, the substrate is taken out of the vacuum furnace and visual inspection, dimension measurement, strength test and the like of the substrate are performed (S306).

By use of the method for joining different kinds of members according to the embodiment of the present invention, the bottom portion bonding material 4 covers the corner between the tip and side portions of the

terminal 1 and thus occurrence of cracks in the corner portion due to concentrated stress can be prevented. Thus, by use of the method for joining different kinds of members according to the embodiment of the present invention, cracks are likely to occur in the substrate, which includes a member vulnerable to thermal stress, in the cooling operation during bonding. Moreover, when the corner radius between the tip and side portions of the terminal 1 is R1 and the corner radius between the bottom and side portions of the terminal bonding hole 8 is R2, the condition of $R1 \geqq R2 \times 0.6$ is satisfied. Accordingly, there is a difference between the corner radius of the terminal 1 and the corner radius of the terminal bonding hole 8. Thus, it becomes easy for the bottom portion bonding material 4 to cover the corner of the tip portion of the terminal 1. Consequently, more sufficient covering is made possible. Furthermore, the corner radius between the tip and side portions of the terminal 1 is set as large as 0.3 mm or more. Thus, the bottom portion bonding material 4 can cover the corner of the tip portion of the terminal 1. Consequently, bonding strength between the substrate and the terminal can be maintained.

(OTHER EMBODIMENTS)

The present invention has been described according to the embodiment described above. It should be understood that the present invention is not limited to the description and drawings which constitute a part of the present disclosure. Various alternative embodiments, embodiments and operational technologies will become apparent to those skilled in the art from the present disclosure.

For example, in the embodiment according to the present invention, the electrostatic chuck was described as an example of the conbonding

member. Besides the electrostatic chuck, the present invention is also applicable to one in which two or more different kinds of members are joined by use of brazing filler metal and the like, for example, a bonding member obtained by joining a porous ceramic member and a metal member having a remarkably high coefficient of thermal expansion and a bonding member obtained by joining ceramic members having different coefficients of thermal expansion from each other or joining metal members having different coefficients of thermal expansion from each other. To be more specific, enumerated are: a bonding member for gas separation, which is formed by joining a porous alumina member used for gas separation and a metal port member to be mounted on various gas analyzers; and the like. It is needless to say that the bonding member according to the present invention also includes a bonding member formed by joining three or more different kinds of members.

Various modifications will become possible for those skilled in the art after receiving the teachings of the present disclosure without departing from the scope thereof.

EXAMPLES

Examples and comparative examples of the present invention will be described below. In the following examples and comparative examples, used was an electrostatic chuck that was a bonding member between a substrate, which included a built-in electrode and was made of aluminum nitride, and a terminal which supplied power to the built-in electrode and was made of gold-plated molybdenum. The electrode was a wire mesh.

(EXAMPLE 1)

The electrostatic chuck was manufactured by the procedure shown in Fig. 2 and bonding of the substrate and the terminal was performed by the procedure shown in Fig. 3. A diameter of the terminal used for the bonding was 5 mm. A corner radius R1 between tip and side portions of the terminal was set to 0.3 mm. Moreover, a corner radius R2 between bottom and side portions of a terminal bonding hole was set to 0.3 mm. In this event, as brazing filler metal, Al-Mg alloy was used. As particles, used were alumina particles having an average particle size of 40 μm, which were Ni-plated in a thickness of 1 to 2 μm. The brazing filler metal and the particles were adjusted in a 1:1 ratio to obtain a bottom portion bonding material 4. Moreover, Al-Ni-Au alloy was used as a side portion bonding material 5. A thickness of the bottom portion bonding material 4 was 0.3 mm and a thickness of the side portion bonding material 5 was 0.05 mm. A corner portion between the tip and side portions of the terminal 1 was covered with the bottom portion bonding material 4. Moreover, conditions of bonding were as below.

Bonding temperature: 700℃

Retention time: 10 minutes

Atmosphere: vacuum (10-3 Pa)

The foregoing bonding test was performed for twenty electrostatic chucks and the number of electrostatic chucks which showed occurrence of cracks was checked. The result is shown in Table 1.

TABLE 1

No.	Terminal diameter (mm)	Corner radius R1 (mm)	Corner radius R2 (mm)	Thickness of side portion bonding material (mm)	Number of no occurrence of cracks (/20)	Yield (%)
Example 1	5	0.3	0.3	0.05	19	95
Example 2	10	0.3	0.5	0.10	18	90
Comparative Example 1	5	0.3	0.8	0.05	10	50
Comparative Example 2	10	0.3	0.8	0.10	9	45
Comparative Example 3	5	0.5	0.3	0.02	10	50
Comparative Example 4	5	0.3	0.8	0.08	8	40
Comparative Example 5	5	0.1	0.5	0.05	8	40

It was confirmed that 19 out of the 20 electrostatic chucks showed no occurrence of cracks and yields were 95 %.

Moreover, Figs. 4A and 4B show cross-sectional SEM photographs, each of which shows the terminal bonding portion used in the example 1. Fig. 4B is an enlarged view of the section A in Fig. 4A. The bottom portion bonding material 4 covers the corner portion of the terminal 1. Moreover, there is no occurrence of cracks in the corner portion.

(EXAMPLE 2)

In the example 2, bonding was performed by using a terminal which had a diameter of 10 mm and a corner radius R1 of 0.3 mm between its tip and side portions. A corner radius R2 between bottom and side portions of a terminal bonding hole 8 was set to 0.5 mm. A thickness of a side portion bonding material 5 was 0.10 mm. The procedure for manufacturing an electrostatic chuck, the procedure for joining the terminal, kinds of a bottom portion bonding material and the side portion bonding material, a thickness of the bottom portion bonding material and bonding conditions were similar to those of the example 1. Moreover, a corner portion of the tip portion of the terminal was covered with the bottom portion bonding material 4. The foregoing bonding test was performed for twenty electrostatic chucks and the number of electrostatic chucks which showed occurrence of cracks was checked. The result is shown in Table 1.

It was confirmed that 18 out of the 20 electrostatic chucks showed no occurrence of cracks and yields were 90 %.

(COMPARATIVE EXAMPLE 1)

In the comparative example 1 for comparison with the examples 1 and 2, bonding was performed by using a terminal which had a diameter of 5 mm and a corner radius R1 of 0.3 mm between its tip and side portions. A corner radius R2 between bottom and side portions of a terminal bonding hole 8 was 0.8 mm. The procedure for manufacturing an electrostatic chuck, the procedure for joining the terminal, kinds and thicknesses of a bottom portion bonding material and the side portion bonding material and bonding conditions were similar to those of the example 1. Moreover, a corner

portion of the tip portion of the terminal was not covered with the bottom portion bonding material. The foregoing bonding test was performed for twenty electrostatic chucks and the number of electrostatic chucks which showed occurrence of cracks was checked. The result is shown in Table 1.

It was confirmed that 10 out of the 20 electrostatic chucks showed no occurrence of cracks and yields were 50 %.

Moreover, Figs. 5A and 5B show cross-sectional SEM photographs, each of which shows the terminal bonding portion used in the comparative example 1. Fig. 5B is an enlarged view of the section B in Fig. 5A. The bottom portion bonding material 4 does not cover the corner portion of the terminal 1. In this event, there was occurrence of a crack C in the substrate 2 from the corner portion of the terminal 1.

(COMPARATIVE EXAMPLE 2)

In the comparative example 2 for comparison with the examples 1 and 2, bonding was performed by using a terminal which had a diameter of 10 mm and a corner radius R1 of 0.3 mm between its tip and side portions. A corner radius R2 between bottom and side portions of a terminal bonding hole 8 was 0.8 mm. The procedure for manufacturing an electrostatic chuck, the procedure for joining the terminal, kinds and thicknesses of a bottom portion bonding material and the side portion bonding material and bonding conditions were similar to those of the example 2. However, similar to the comparative example 1, a corner portion of the tip portion of the terminal was not covered with the bottom portion bonding material 4. The foregoing bonding test was performed for twenty electrostatic chucks and the number of electrostatic chucks which showed occurrence of cracks was checked. The

result is shown in Table 1.

It was confirmed that 9 out of the 20 electrostatic chucks showed no occurrence of cracks and yields were 45 %.

(COMPARATIVE EXAMPLE 3)

In the comparative example 3 for comparison with the examples 1 and 2, bonding was performed by using a terminal which had a diameter of 5 mm and a corner radius R1 of 0.5 mm between its tip and side portions. A corner radius R2 between bottom and side portions of a terminal bonding hole 8 was 0.3 mm. A thickness of a side portion bonding material 5 was 0.02 mm. The procedure for manufacturing an electrostatic chuck, the procedure for joining the terminal, kinds of a bottom portion bonding material and the side portion bonding material, a thickness of the bottom portion bonding material and bonding conditions were similar to those of the example 1. However, similar to the comparative example 1, a corner portion of the tip portion of the terminal was not covered with the bottom portion bonding material 4. The foregoing bonding test was performed for twenty electrostatic chucks and the number of electrostatic chucks which showed occurrence of cracks was checked. The result is shown in Table 1.

It was confirmed that 10 out of the 20 electrostatic chucks showed no occurrence of cracks and yields were 50 %.

(COMPARATIVE EXAMPLE 4)

In the comparative example 4 for comparison with the examples 1 and 2, bonding was performed by using a terminal which has a diameter of 5 mm and a corner radius R1 of 0.3 mm between its tip and side portions. A

corner radius R2 between bottom and side portions of a terminal bonding hole 8 was 0.8 mm. A thickness of a side portion bonding material 5 was 0.08 mm. The procedure for manufacturing an electrostatic chuck, the procedure for joining the terminal, kinds of a bottom portion bonding material and the side portion bonding material, a thickness of the bottom portion bonding material and bonding conditions were similar to those of the example 1. However, similar to the comparative example 1, a corner portion of the tip portion of the terminal was not covered with the bottom portion bonding material 4. The foregoing bonding test was performed for twenty electrostatic chucks and the number of electrostatic chucks which showed occurrence of cracks was checked. The result is shown in Table 1.

It was confirmed that 8 out of the 20 electrostatic chucks showed no occurrence of cracks and yields were 40 %.

(COMPARATIVE EXAMPLE 5)

In the comparative example 5 for comparison with the examples 1 and 2, bonding was performed by using a terminal which had a diameter of 5 mm and a corner radius R1 of 0.1 mm between its tip and side portions. A corner radius R2 between bottom and side portions of a terminal bonding hole 8 was 0.5 mm. A thickness of a side portion bonding material 5 was 0.05 mm. The procedure for manufacturing an electrostatic chuck, the procedure for joining the terminal, kinds of a bottom portion bonding material and the side portion bonding material, a thickness of the bottom portion bonding material and bonding conditions were similar to those of the example 1. However, similar to the comparative example 1, a corner portion of the tip portion of the terminal was not covered with the bottom portion

bonding material 4. The foregoing bonding test was performed for twenty electrostatic chucks and the number of electrostatic chucks which showed occurrence of cracks was checked. The result is shown in Table 1.

It was confirmed that 8 out of the 20 electrostatic chucks showed no occurrence of cracks and yields were 40 %.

(CONCLUSION)

It was confirmed that the yields in the examples 1 and 2 were as high as 90 to 95 % while the yields in the comparative examples 1 to 5 were 40 to 50 %. Therefore, it was confirmed that cracks were unlikely to occur when the bottom portion bonding material 4 covered the corner portion of the terminal. Furthermore, it was confirmed that cracks were unlikely to occur when the corner radius R1 of the tip portion of the terminal was 0.3 mm or more. Moreover, in the examples 1 and 2, the corner radius R1 between the tip and side portions of the terminal and the corner radius R2 between the bottom and side portions of the terminal bonding hole satisfied the condition of $R1 \geqq R2 \times 0.6$. Furthermore, the thickness of the side portion bonding material 5 was 0.008 to 0.012 times the diameter of the terminal in the examples 1 and 2 while the thickness thereof was outside of this value range in the comparative examples 3 and 4.